PATENT SPECIFICATION

1,057,015

DRAWINGS ATTACHED.

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Int. Cl.:—B 01 d.

COMPLETE SPECIFICATION.

Improvements in or relating to a Method and Apparatus for Dynamic Filtration of Slurries.

We, JAN KASPAR, No. 1332, Ukostelicka, Pardubice, JOSEF SOUDEK, No. 1293, Sezemicka, Pardubice, KAREL GUTWIRTH, No. 116, Strossova, Pardubice, all in Czechoslovakia, all Czechoslovakian citizens, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a method of and apparatus for dynamic filtration of slurries.

Filtration of difficultly filtrable slurries is carried out on an industrial scale by means of pressure filters of various type, such as filter-presses, continuous drum pressure filters, belt pressure filters, and automatic filter-presses. The drawback of all these apparatus is the considerable specific weight or volume coming to 1 m^2 of the filtration surface, high investment cost, high consumption of pressure gas produced with low energetic effectiveness. The disadvantage of filter-presses lies in the wear of the filter cloths, due to frequent disassembling and redipping and to the high pressure, and in the consumption of manpower under heavy working conditions. With the continuously working pressure filters, there are also troubles with the discharge of the cake from the pressure space, with the mode of stretching and driving the filter cloth, and of tight sealing of the movable parts.

The greatest drawback is the low specific capacity of the apparatus, coming to the unit of the filtration surface.

It is an object of the present invention to obviate or mitigate the aforesaid disadvantages.

The present invention is a method of dynamic filtration of slurries and any other suspensions, by means of a filtration diaphragm, in which the filtration cake is removed from the filtration diaphragm and mixed up with the unfiltered slurry, whereat said mixture is kept in liquid state by agitation.

The present invention is also an apparatus for dynamic filtration of slurries comprising a pressure vessel provided with supply and discharge branches and regulation valve means for controlling the discharge of the mixture of the suspension with the filtration cake, with a gasket placed in the vessel axis and sealing a rotatable hollow shaft, on which, inside the pressure vessel is at least one filtration diaphragm.

An embodiment of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:—

Fig. 1 is a graphic illustration of the equation $(V+V_o)^2=C(t+t_o)$,

Fig. 2 is a graphic illustration of the relationship between symbols S and *v*,

Fig. 3 is an elevation of apparatus for dynamic filtration of slurries according to the invention,

Fig. 4 is an elevation of the filtration body according to one embodiment,

Fig. 5 is an elevation of a filtration body according to a modification,

Fig. 6 is a sectional elevation of the filtration diaphragm according to one embodiment of the present invention,

Fig. 7 is a sectional elevation of a modified filtration material,

Fig. 8 is a side elevation and plan of discharge means,

Fig. 9 is a side elevation and plan of modified discharge means,

Fig. 10 is a block diagram illustrating the connection of three dynamic filters, and

Fig. 11 is a further modified discharge means.

Fig. 12 shows the flow of liquid,

Fig. 13 shows the dependence of the viscosity on the value Dr,

Fig. 14 shows the viscosity of the suspension as a function of the concentration of the solid phase in the suspension with a constant rate-gradient.

Fig. 15 represents a sectional view of a filtration surface.

The difficulties are inherent in the mechanism of filtration and washing. Assuming filtration under constant pressure, there holds the relation between the volume V of the filtrate passed through, and time t:

$$(V+V_o)^2=C\ (t+t_o)$$

The constants V_o and t_o characterize the qualities of the filtration medium, the constant C characterizes the quality of the filtration cake and filtrate and the influence of pressure. This equation is graphically reproduced in Fig. 1. Regarding the fact that the thickness of cake is directly dependent on the quantity of the filtrate passed through, it is possible to express the relation between the cake thickness S and filtration rate v on the basis of the above relationship, the general form of said relationship being illustrated by Fig. 2. From this graph, the non-linear decrease of the filtration rate with increased cake thickness is evident.

In order to obtain the solid phase (filtration cake) as pure as possible, it is often necessary to wash the cake with a wash liquid. If the product is contained in the filtrate, then it is necessary to obtain the maximum quantity of the filtrate by washing.

As a rule, washing proceeds at constant flow rate of the wash liquid. Therefore, by keeping the same pressure drop, and the same viscosity of the wash as of the filtrate. the flow rate of the wash is equal to the final filtration rate.

The time of washing is dependent on the desired degree of removal of the soluble substance from the cake. In washing it is advantageous to use at the start a washing liquid already containing a certain percentage of the soluble substance (especially in continuous operations). With the increasing degree of washing, gradually purer wash liquid portions are used, up to the use of absolutely pure liquid for the ultimate wash.

With discontinuous apparatus this washing method would require a series of large volume storage reservoirs, and also a relatively complicated handling. With continuous apparatus it is necessary in this case to divide the washing operation into several stages, which is no less troublesome. That is why in such case almost all the wash operation is carried out with pure liquid, the consumption of which is consequently higher, while the percentage of substances dissolved is relatively low.

In case harmful substances that cannot be freely discharged, e.g. into watercourses, are to be removed from the filtration cake by washing, then the neutralization of the wash becomes burdensome and expensive in view of the great volume and low concentration.

In the manufacture of dispersed dyes the aim is at obtaining a product with particles as fine as possible, of a size of about 1—2 microns. This can be achieved directly in their preparation though, but the filtration and washing of suspensions containing particles of extreme fineness is very difficult and mostly not feasible on operational scale, in consequence of blinding the filtration medium and great resistance of the filtration cake.

With the most hardly filtrable slurries there is attained about 20—30 vol. % dry substance in the filtration cake, which so long as it is left at rest shows thixolabile properties and behaves as a paste. If to such paste 2—5% of a liquid or a reasonable amount of a dispersion agent is added, and as the case may be, the paste is subjected to intensive agitation, the paste begins to flow.

Let us conceive that, according to Fig. 12, the flow of the liquid in space is such that different speeds U_a, U_b occur in the individual points A, B. In this Figure we also indicate the lines of flow a, b, of the individual liquid elements. If l is the distance between the lines of flow, the rate gradient (velocity gradient) D_r between the lines A and B can be expressed as

$$D_r=\frac{\Delta u}{\Delta l}=\frac{U_a-U_b}{l}$$

It is known that the viscosity η of non-Newtonian liquids depends on the value of the above rate-gradient D_r.

Thixolabile materials are also characterised therein that their viscosity is a function of the velocity of the mutual displacement of the individual layers. Vis-

cosity gradually diminishes until, after a certain time, it attains a value which is a function of the value D_r.

Fig. 13 shows the dependence of the viscosity on the value D_r.

It is also known that, at a constant rate-gradient, the viscosity of the suspension is a function of the concentration W of the solid phase in the suspension, as shown in Fig. 14.

This knowledge has now been used in suggesting the method and apparatus for dynamic filtration.

The method of dynamic filtration, according to the invention, consists in that the filtration cake that under normal operation would be formed on a filtration diaphragm, is fully or partly removed from the diaphragm, and is mixed up with the unfiltered slurry, and this mixture is so intensively agitated as to become liquid. The removal of the filtration cake can be attained either by the action of stirring under a suitable rate gradient of the mixture (of the original slurry and cake), and if need be, by addition of 5—50 vol. % solid particles of a size at least 10-fold of the average particle size of the unfiltered slurry, or by means of an auxiliary diaphragm. The viscosity can be decreased and the desired fluidity attained by addition of a suitable surface active substance

Fig. 15 represents a sectional view of a filtration surface fitted with a diaphragm (partition) 8, a plate 43 and a perforated plate 44.

The space between the partition 8 and the plate 43 is filled with a mixture of the suspension and the cake. The plate 43 moves in the indicated direction having a velocity u with respect to the filtering diaphragm 8, l being the distance between the latter and the plate 43. Thus the mixture of the suspension and the filtration cake is mixed at a rate (velocity) gradient

$$D_r = \frac{u}{l}.$$

It has been found that, in order to attain the above mentioned effects, i.e. to constantly remove the filtration cake from the filter cloth and to add it to the suspension and to keep this mixture in a fluid state, it is necessary to maintain a certain value D_r which depends on the properties of the suspension. In certain instances, a value of $D_r = 70\ \text{sec}^{-1}$ will prove sufficient, in other cases a value of $D_r = 500\ \text{sec}^{-1}$ will be required. These limits, however do not indicate the extent of all possibilities.

A special advantage of the filtration method, is that the slurry to be thickened is continuously moved along the filtration diaphragm from the position of supply of the slurry up to the position of discharge of the cake.

It has been established by extensive experiments that in this way a concentration by 10—20% higher of the solid substance in the cake can be attained, than with any of the so far known pressure filters.

The basic arrangement of the apparatus for carrying out the filtration with the above described method is suggested in Fig. 3. The apparatus consists of a pressure vessel *1* provided with a neck, through which passes a hollow shaft *3*, packed by a gasket *2*. Inside of the vessel, on the shaft *3* is a hollow filtration body *4*. The pressure vessel *1* is provided with a neck *5* for the intake of the slurry, and with a neck *6* for the discharge of the thickened slurry. The neck *6* is fitted with a regulation valve *7* and on the faces of the filtration body *4* filtration diaphragms *8* are fixed.

The above described apparatus operates in the following manner:—the slurry is continuously fed under a constant rate into the vessel *1* through the neck *5*, being intensively agitated by the rotating filtration body *4* and the filtrate which passes through the filtration diaphragms *8* flows away from the filter through the hollow shaft *3*. At the start of filtration the regulation valve *7* remains closed until the optimum concentration in the vessel *1* is achieved. In the following normal operation the discharge by the neck *6* is controlled so as to keep the optimum slurry concentration in the vessel *1*. The apparatus may be arranged in a vertical, horizontal or inclined position as required. The shape of the vessel *1* may be of various forms and is more or less determined by the shape of the filtration body *4*. The vessel may be built-up of a cylinder provided with flat heads, dished or conical bottoms, or of various combinations of these structural elements under contingent restriction or even omission of the cylindrical part.

The modified filtration body *4a*, according to Fig. 4, may have the shape of a cylinder with a filtration diaphragm *8a* fixed on the cylindrical part or also on the heads thereof. Another shape of the body is illustrated in Fig. 5, where the filtration body *4b* is built-up of two truncated cones. According to Fig. 3 the body *4* has the shape of a hollow disc, and there may be mounted several such bodies in a single vessel *1*. In order to intensify the agitation of the filter content the filtration bodies *4, 4a, 4b* may be provided with ribs or blades 9 (as shown in Fig. 5). Agitation may be intensified by placing the filtration body *4* in the vessel *1* such that its axis is mounted eccentrically to the axis of

the vessel *1* though parallel with it, or mounted in colinear or transverse position with regard to the axis of the vessel *1*.

The filtration diaphragm *8* may consist of a single or several layers of the filtration material with either equal or different size of openings, whereas the surface layer may be made of a material resistant to abrasive wear. Since in the dynamic filter the filtration cake may be continuously removed from the diaphragm surface, no filtration film, otherwise necessary for retaining the most fine portions of the suspended solid substance, is formed on the diaphragm. This principle can be used for separation of fine particles from the coarser ones. In this case, the fine particles are led away with the filtrate. If a complete retainment of solid particles is required, this disadvantage may be obviated according to Fig. 6 wherein there is an auxiliary filtering partition 11, for instance a sieve, applied to the basic filtering material 10, the meshes of which are substantially larger than those of the filtering diaphragm 10. The suspension is located on the upper side of the sieve 11. Even with an intensive mixing, the cake 12 will be deposited in the openings (meshes) of the sieve 11 so as to form an auxiliary filtering layer (filter bed). Even the finest particles will get caught by this layer. Another method of obtaining an auxiliary filtering layer is depicted in Fig. 7. Spacers 15 are placed between two layers of the filtering materials 13 and 14; the solid particles pass through the filtering diaphragm 14, but are caught by the filtering diaphragm 13 because the surface of the latter is not washed (cleansed). The rigid particles fill up the apertures in the spacer 15. No fine particles can pass through this filtering cake any more.

In dynamic filters the take-off of the filtrate from the interior of the filtration body *4* can be effected in several ways. In Fig. 3 complete filling up of the filtration body interior to overcome the centrifugal force and other resistances by pressure increase in the filter is assumed. In Fig. 8 the discharge is effected by means of a fixed diffuser disc *17*, situated inside a rotating filtration body *4c*, and also by means of a discharge pipe *18* passing through the shaft *3a*. The discharge according to Fig. 9 is carried out in an analogous manner: instead of the diffuser disc a fixed Segner wheel 19 is employed.

The abovedescribed method of and apparatus for dynamic filtration makes it possible to perform the washing operation by several steps, whereat during the operation the wash liquid is gradually enriched with the soluble component by washing the thickened slurry with the wash already used and containing a certain portion of the soluble substance.

In Fig. 10 the connection of three dynamic filters for filtration and two-stage washing is represented.

Numerals *1*, *21* and *31* represent the vessels of dynamic filters in the abovedescribed execution. The discharge neck *6* of the vessel *1* is interconnected by a line *20* with an intake neck *22* of the vessel *21*. The discharge neck *24* of the vessel *21* is interconnected by a line *26* with the intake neck *27* of the vessel *31*. The vessel *31* is provided with a neck *30* for the discharge of the thickened and washed slurry, and with a hollow shaft *29* for carrying away the wash liquid filtered off. Similarly, the vessel *21* is provided with a hollow shaft *23* for carrying away the wash liquid.

To the line *26* a branch *25* is attached for admission of the pure wash liquid. The hollow shaft *29* is interconnected by a line *28* with a pump *32*, and said pump *32* by a line *33* with a branch *34*, connecting it with the line *20*.

The apparatus operates in the following manner: the slurry to be filtered is fed continuously into the vessel *1* with constant rate and the filtrate flows off by the hollow shaft *3*. The thickened slurry is carried away by the branch *6* and the line *20* into the branch *22* of the vessel *21*. Into the line *20*, by the branch 34, the partly saturated wash liquid is fed in. The mixture of the thickened and not yet washed slurry with the partly saturated wash liquid is thoroughly mixed up in the vessel *21*. In said vessel *21* the saturated wash liquid is filtered off in the abovedescribed manner, and goes out to the waste through the hollow shaft *23*. The partly washed and condensed slurry flows off by the branch *24* and the line *26*, wherein it is mixed with the pure wash liquid fed in by the branch *25*, and enters the branch *27* of the vessel *31*. In said vessel *31* the mixture is stirred up, and the partly saturated and filtered off wash liquid flows off through the hollow shaft *29*. The washed and condensed slurry is discharged from the vessel *31* by the branch *30*. The partly saturated wash liquid is led away by the pipe *28* to the pump *32*, conveying it by the line *33* into the branch *34*.

Similarly, the condensed slurry can be filtered and washed in *n* stages with aid of n+1 dynamic filters.

The apparatus described can be alternatively arranged also in a single common vessel provided with partitions, filtration bodies *4*, *4a*, *4b* mounted on a common hollow shaft *3* having independent channels for carrying off the filtrate and the wash liquid, having the abovedescribed

functional interconnection of the parts of the apparatus.

Another arrangement is depicted in Fig. 11. The apparatus consists of a vessel *35*, inside of which a hollow plate *36* with a filtration diaphragm *37* is placed, said vessel being provided with a discharge neck *41*. In the head of the vessel is the gasket *40*, through which passes a shaft *39* on which a disc *38* is fixed. The head is provided with the admission pipe *42*.

The function of the apparatus above-described is as follows:—

the slurry to be filtered is fed in by the neck *42*, passes through the gap between the fixed plate *36* with the filtration diaphragm *37* and the disc *38*, and after having been condensed it is discharged from the filter by the neck *43*. The filtrate is discharged from the hollow plate *36* by the neck *41*. Owing to rotation of the disc *38* the filtered slurry is exposed to shear forces, which are manifested by shifting the layers of the slurry, thus causing removal of solid particles from the filtration diaphragm and remixing them with the whirling slurry. The shift is proportional to the overall rate gradient, which in turn is directly proportional to the peripheral velocity, and inversely proportional to the width of the gap between the fixed and the rotating disc. Alternatively the rotating disc *38* can be replaced by any other type of stirrer, e.g. by an arm agitator (not shown).

The apparatus according to Fig. 3 and 11 can also be combined to advantage, and as the case may be, combined in addition with an arrangement, according to which in the vessel a number of hollow plates *36* are placed, bearing on the one or the two sides the filtration diaphragm *37*, and on the hollow shaft a number of filtration bodies *4* with filtration diaphragms *8* on both sides, whereat the fixed hollow plates *36* alternate with the filtration bodies *4*, with a reasonable interspace therebetween.

The method of and apparatus for dynamic filtration, according to the invention, has the following merits:

a) the specific capacity of an apparatus having 1 m^2 of filtration surface is several times higher than that of any of the known apparatus for pressure filtration, since the filtration is carried out continuously under constant and low specific resistance of the filtration diaphragm, and with a minimum layer of the filtered material, and since the lost time, usual with discontinuous apparatus, is eliminated,

b) the apparatus is simple, and therefore the investment cost per 1 m^2 of surface, or eventually per unit of the material filtered, is substantially lower than with the so far known apparatus,

c) owing to the countercurrent system only a low volume of the wash liquid is necessary, and the wash flowing off is fully saturated,

d) auxiliary apparatus needed for the operation is minimum, consisting only of dosing pumps; large reservoirs are made superfluous.

In view of continuous operation, the apparatus can be automatized and placed in an open area, thereby minimizing the demands on area and for structural rooms.

Fine dye dispersions can be prepared intentionally already in the preparation stage, since their filtrability is secured by the method. Thereby also the demands made on a contingent additional grinding apparatus are reduced.

WHAT WE CLAIM IS:—

1. The method of dynamic filtration of slurries and any other suspensions by means of a filtration diaphragm, in which the filtration cake is removed from the filtration diaphragm and mixed up with the unfiltered slurry, whereat said mixture is kept in liquid state by agitation.

2. A method as claimed in claim 1, in which the filtration cake is removed from the diaphragm by agitation at an adequate rate gradient of the slurry to be thickened in the space beyond the diaphragm.

3. A method as claimed in claim 1 or 2, in which the unfiltered slurry has added to it 5—50 vol. % of solid particles of a size at least 10 times larger than the size of the particles in the unfiltered slurry.

4. A method as claimed in any one of the preceding claims in which the slurry to be thickened is continuously moved along the filtration diaphragm, from the intake of the slurry up to the outflow of the cake from the filter.

5. A method as claimed in any one of the preceding claims, in which the filtration cake is removed mechanically with the aid of an auxiliary diaphragm.

6. A method as claimed in claim 4 or 5 in which the fluidity of the thickened slurry is increased by addition of a surface active substance to the slurry to be thickened.

7. Apparatus for dynamic filtration of slurries comprising a pressure vessel provided with supply and discharge branches and regulation valve means for controlling the discharge of the mixture of the suspension with the filtration cake, with a gasket placed in the vessel axis and sealing a rotatable hollow shaft, on which, inside the pressure vessel is at least one filtration diaphragm.

8. Apparatus as claimed in claim 7, in which each filtration diaphragm is mounted at least at one side of a filtration body of revolution which forms a hollow filtration body.

9. Apparatus as claimed in claim 7, in which each filtration diaphragm is mounted on a hollow plate, being mounted on at least one side thereof.

10. Apparatus as claimed in claim 8, in which the filtration body has the shape of a cylinder bearing the filtration diaphragm fixed on the cylindrical part, contingently also on the heads thereof.

11. Apparatus as claimed in claim 8, in which the filtration body is formed of two truncated cones, on which the filtration diaphragm is fixed.

12. Apparatus as claimed in claim 8, in which the filtration body has the shape of a hollow disc, on the sides of which the filtration diaphragms are fixed.

13. Apparatus as claimed in any one of claims 10, 11 and 12, in which the filtration bodies are provided with blades.

14. Apparatus as claimed in claim 8, in which a fixed diffuser wheel, is built into the filtration body provided with a discharge pipe which passes through the shaft.

15. Apparatus as claimed in claim 8 in which a fixed Segner wheel is built into the filtration body and provided with a discharge pipe passing through the shaft.

16. Apparatus for dynamic filtration of slurries substantially as hereinbefore described with reference to and as illustrated by Figs. 3 to 11 of the accompanying drawings.

17. A method of dynamic filtration of slurries substantially as hereinbefore described with reference to and as illustrated by the accompanying drawings.

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Fig. 1

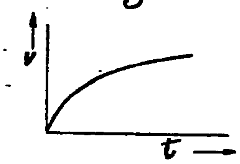


Fig. 2

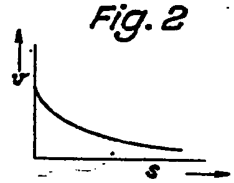
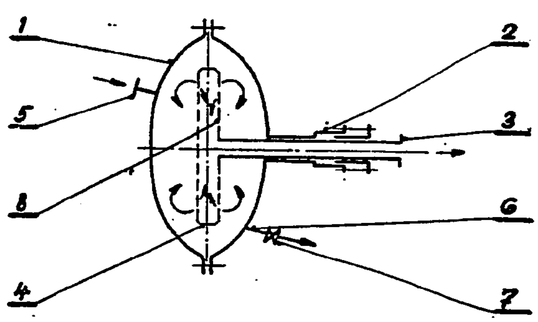
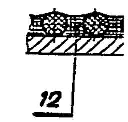


Fig. 3





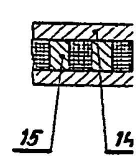


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FIG. 12.

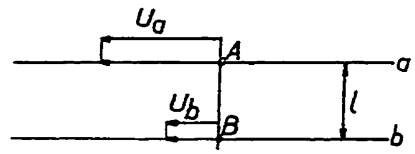

Fig. 4

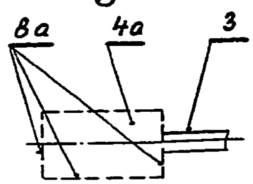

FIG. 13.

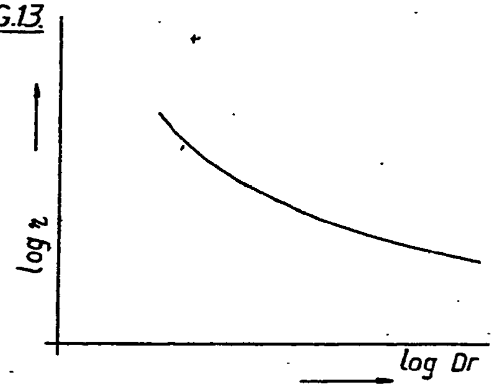

Fig. 5

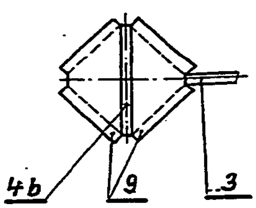

FIG. 14.

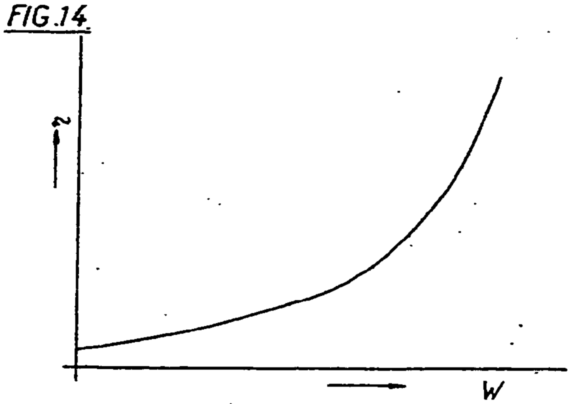

Fig. 6

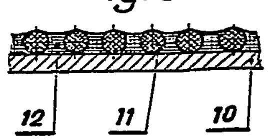

Fig. 7

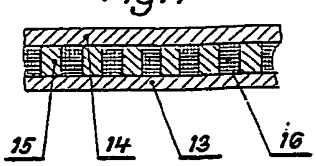

FIG. 15

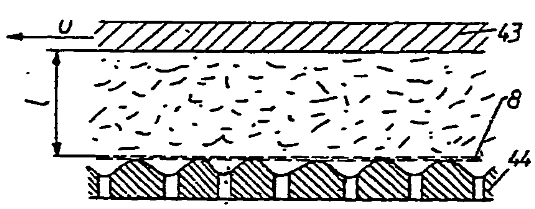

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FIG.12.

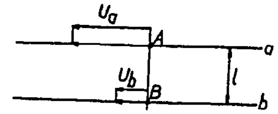


Fig.1

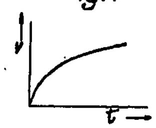


Fig.4

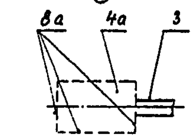


FIG.13.

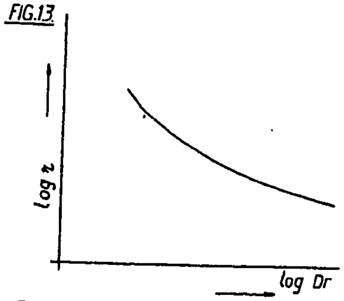


Fig.2

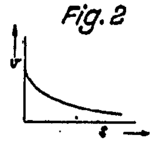


Fig.5

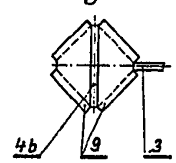


FIG.14.

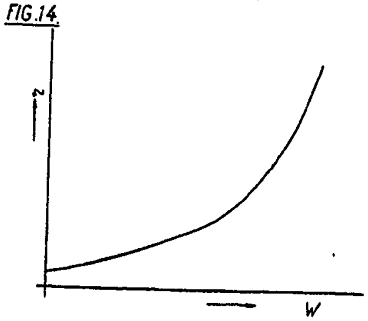


Fig.6

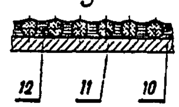


Fig.3

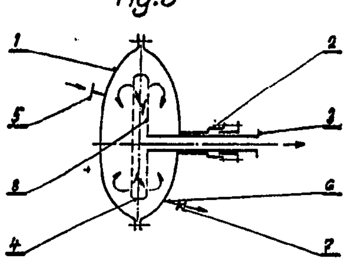


Fig.7

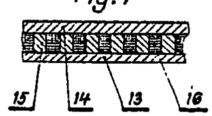


FIG.15.

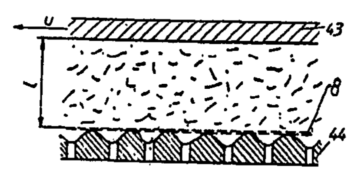


Fig.8

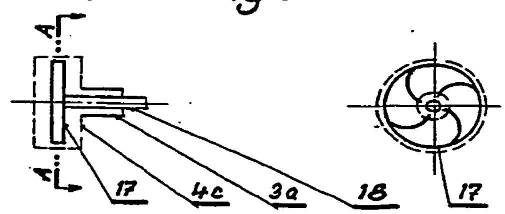


Fig.9

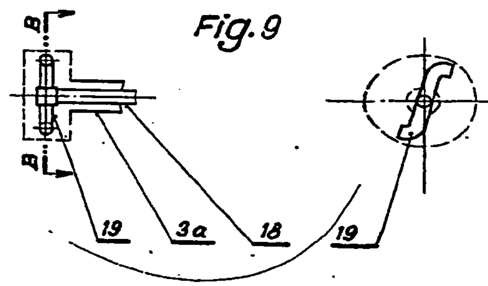
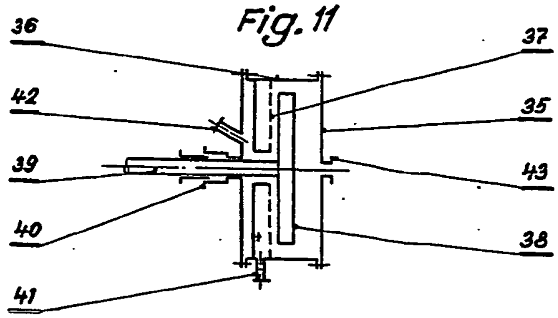
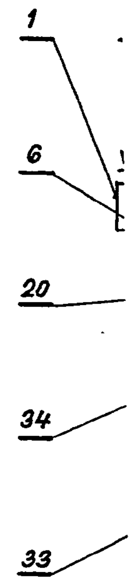


Fig.11





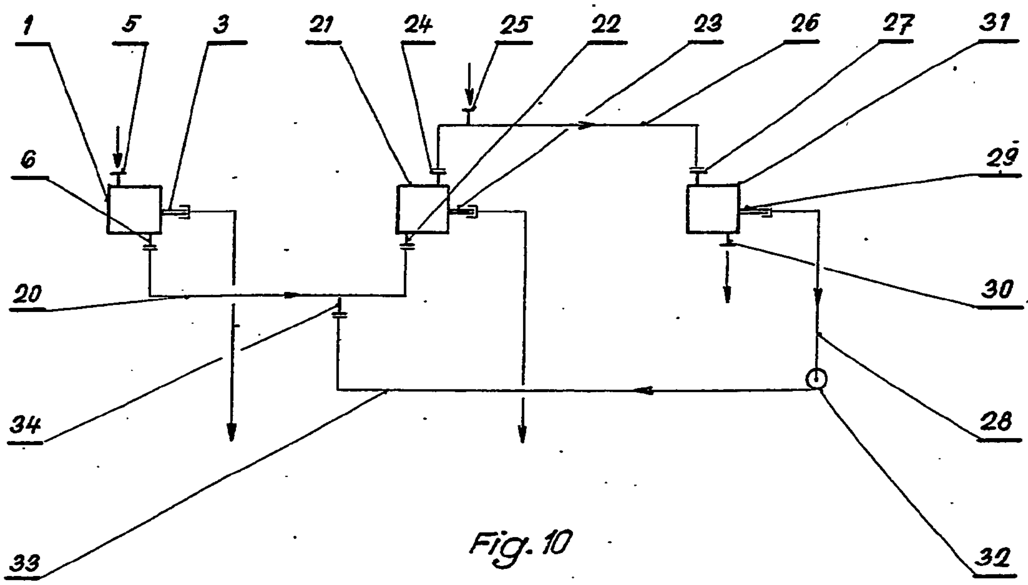


Fig. 10

1057015 COMPLETE SPECIFICATION

4 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 3

Fig. 8

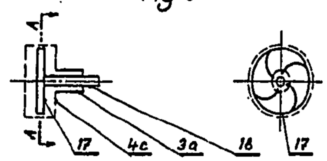


Fig. 9

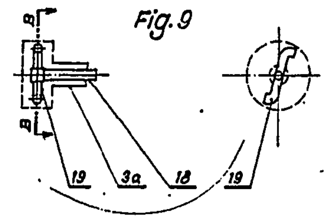
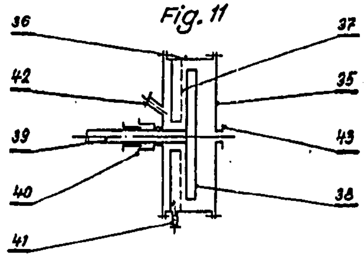


Fig. 11



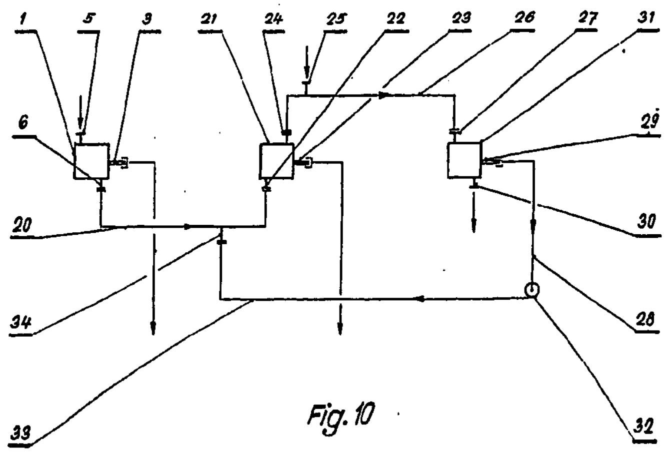


Fig. 10